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CHECKLIST

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A checklist of vascular plants of Ewe-Adakplame Relic Forest in Benin, West Africa

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Abstract

Covering 560.14 hectares in the south-east of Benin, the Ewe-Adakplame Relic Forest (EARF) is a micro-refugium that shows insular characteristics within the Dahomey Gap. It is probably one of the last remnants of tropical rain forest that would have survived the late Holocene dry period. Based on intensive field investigations through 25 plots (10 × 50 m size) and matching of herbarium specimens, a checklist of 185 species of vascular plant belonging to 54 families and 142 genera is presented for this forest. In addition to the name for each taxon, we described the life form following Raunkiaer's definitions, chorology as well as threats to habitat. The Rubiaceae family was the richest (20 species) followed by the Fabaceae (15 species). Life forms showed the preponderance of phanerophytes (88%). The Chorological spectrum was dominated by Guineo-Congolean species (66%). Species richness estimated were 200.52 ± 9.2808 for *Bootstrap*; 217.62 ± 14.5972; 224.16 ± 15.3725 and 242.67 respectively for *Chao*, *Jacknife1* and *Jacknife2*. *Bootstrap* appears to be the estimation closer to the field records. In Benin, EARF is home for *Rinorea* species described as West African forest bio-indicators and single location for *Nesogordonia papaverifera*, *Mansonia altissima*, *Englerophytum oblanceolatum*, *Octolobus spectabilis*, *Vitex micrantha* and most of *Drypeteae* tribe species (*Drypetes aframensis*, *Drypetes afzelii*, *Drypetes gilgiana* and *Drypetes leonensis*) recorded in Benin. Our results provides baseline information for further in-depth analysis of vegetation history in Benin by raising the question on the past floristic connection of the Dahomey gap and community engagement in conservation.

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Keywords
Dahomey Gap, Flora, Kétou, Range-restricted species, Refugial

Introduction

At the continental level, African rain forests, primarily those of the Guineo-Congolean block, are the main centres of species diversity (White 1983; Lebrun 2001; Sosef et al. 2017; Droissart et al. 2018; Couvreur et al. 2021). However, in some regions of this block, landscape changes have been so severe that particular areas would have functioned as refugia, while diversity in surrounding areas would have experienced losses. This is probably the case with forest islands within the Dahomey Gap which is the dry corridor separating the West African rain forest into the Upper Guinean and Lower Guinean blocks (White 1983; Jenik 1994; Poorter et al. 2004). During the late Holocene dry period (3000–2500 yrs BP), the once continuous rain forest belt became fragmented and was reduced to isolated patches that would have persisted and survived as "small isolated humid pockets" (Dupont and Weinelt 1996; Salzmann and Hoelzmann 2005). In addition to these historical climatic oscillations, archaeologists and ecologists highlighted several proofs of human footprint such as metallurgy (cast iron), agriculture, pottery that would have gradually caused deforestation and may explain the phytogeographic status of the Dahomey gap in West Africa (Richards 1973; Paradis 1977; Wantchecon 1983; Brand 2001; Garnier et al. 2018). Indeed, this savanna intermingled with small forest patches within the Dahomey gap, is also seen as a cultural landscape, produced by humans for subsistence, security and/or worship uses of religious traditions (Juhé-Beaulaton 2010; Cousin 2018). Consequently, the vegetation of Benin which is supposed to be luxuriant is today largely dominated by farms, fallows and grasslands (Adjanohoun 1966; Jenik 1994; Sosef et al. 2017). One fifth of the original forests remain, fragmented into isolated patches (Poorter et al. 2004). Today, Benin is home to 2807 plant species in terms of floristic composition (Akoègninou et al. 2006). It is among the best explored botany countries of sampling completeness with 2460 species theoretically estimated between 2864 and 2889 species (Sosef et al. 2017). Despite this sampling effort, some species that have not yet been collected or reported may not be listed and therefore omitted. Either because they may have disappeared, following their habitat degradation, as was the case of *Chrysobalanus icaco* L. (Syn. *C. atacoriensis* A. Chev.), which would have disappeared following earthworks (Adjanohoun et al. 1989).

However in Benin, most of these remaining forest patches, although playing the role of a high conservation priority area for heritage plants, are still experiencing severe threats due to the lack of adequate conservation strategies (Oloukoï et al. 2007; Adomou et al. 2010). This is probably the case with Ewe and Adakplame Relic Forest (EARF) in the south east of Benin. Up to now, this relic still persists on a community land while showing insular characteristics with some rare and poorly known plant species. Earlier

botanists who worked on this refugium include Chevalier (1910), Aubréville (1937) and Adjanohoun (1966). They noted the typical feature of the Ewe-Adakplame Relict Forest (EARF) described as a Timber-refuge of the time of tribal wars, as one having a considerable number of African rain forest species of Guineo-Congolean region comparable to those of Côte d'Ivoire (Adjanohoun et al. 1989, P. 20).

In this context, floristic details on EARF may be very useful for conservation purposes through restoration and rehabilitation of degraded land with native trees. Such information is necessary for further studies in biogeography and phylogeny on the one hand, to address the main speciation models and mechanisms that may apply across tropical Africa (Demenou et al. 2016, 2018; Couvreur et al. 2021), and on the other hand to reconstruct the history of Tropical Africa vegetation.

This paper aims to provide a comprehensive checklist of vascular plants occurring in EARF that will serve as baseline for understanding the history of this vegetation over millennia. By exploring the floristic composition of EARF, we can better appreciate the biogeographic status of some species previously reported by Achoundong (1996; 2000) as bio indicators in other West African forests located on either side of the Dahomey gap. The results could help (1) to better understand how the Dahomey Gap has affected the vegetation of this area and (2) to catalyze long-lasting conservation actions toward EARF.

Methods area

Study site

The EARF covers 560.14 hectares in the Kétou District in the south-east of Benin Republic at 07°27'59.195"N, 002°34'29.395"E (Fig. 1). This part of the country belongs to the Guineo-Congolean Region (White 1983; Adomou et al. 2006). The forest relic is located at the north-east of the depression of "Co" or "Lama" on the plateaus of low altitude that evolved on the pre-Cambrian base rocks (Adjanohoun et al. 1989). In Benin, the most important national protected areas are in the north. There are several other forests (albeit small) in the southern part of the country which are within the national protected areas network (e.g. gazetted forests of Dogo-Ketou, Pobe, Lama, Pahou) which are well-managed (Adomou et al. 2006). There is also the recent Transboundary biosphere reserve of Mono which is now part of the national protected areas network. However, EARF has not yet been included in this national protected areas network.

The mean annual rainfall in the EARF is between 900–1300 mm (Adjanohoun et al. 1989; CARDER 2002; Adomou et al. 2006) which contrasts to other similar African dense semi-deciduous forests. The rainfall recorded in Upper Guinea is between 1750–1900 mm (Martin 2008) in Côte d'Ivoire (West Africa) and annual rainfall measured around the Kakamega rain forest in East Africa was approximately 2215 mm (Cords 1987) and 1956 mm (Greiner 1991). Table 1 provides parameters such as temperature, relative humidity, vegetation and soil types of the study site. The

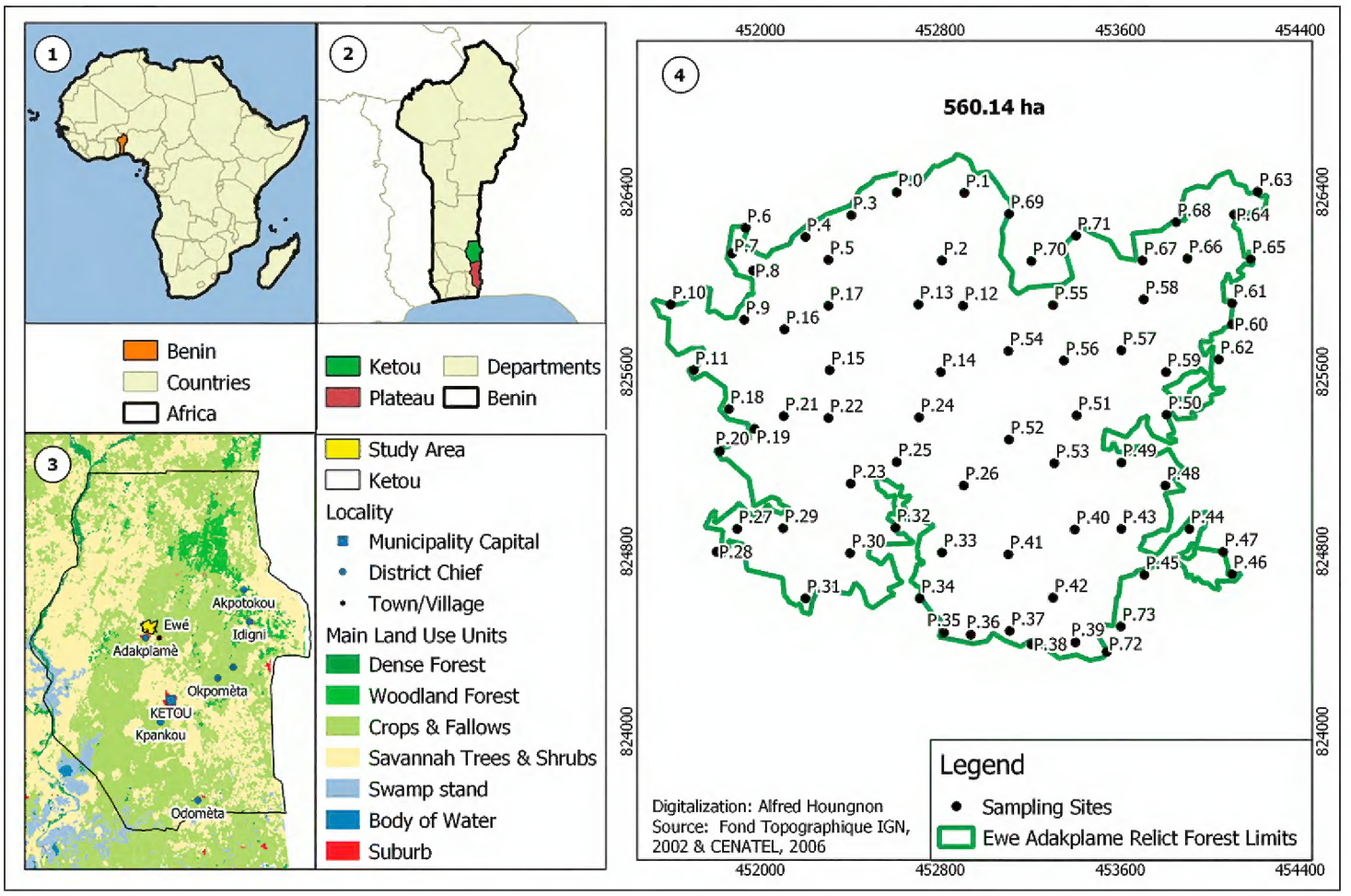


Figure 1. Location of the Ewe-Adakplame Relict Forest in Benin and positions of the sampling stands.

Table 1. Ecological characteristics of the study region.

Location	6°25–7°30N	Adjanohoun et al. (1989) Adomou et al. (2006)
Annual rainfall	900–1100 mm	CARDER 2002, Adomou et al.(2006)
Rainfall trend	Bimodal	Adjanohoun et al. (1989)
Rainy season(s)	March–July & September–October	Adjanohoun et al. (1989) Adomou et al. (2006)
Dry season	August and November–February	Bani (2006)
Temperature	24–37 °C	CARDER (2002), Bani (2006)
Insolation	2135 h	CARDER (2002), Bani 2006
Relative humidity	78–95%	CARDER (2002), Bani (2006)
Climate type	Sub-equatorial	Adomou et al. (2006)
Length of plant growing season	240 days	CARDER (2002), Bani (2006)
Vegetation	Mosaic of Savanna	Adjanohoun et al. (1989) Adomou et al. (2006)
Soil types	Ferralitic soils without concretion	Adjanohoun et al. (1989), Bani (2006)
Altitude	200–286 m above sea level	Bani (2006)

landscape surrounding EARF is dominated by fallows, cultivation areas and housing. The vegetation is a mosaic of savanna with species of the Sudanian transition zone such as *Adansonia digitata* L., *Stereospermum kuntianum* Cham., *Trichilia emetic* Vahl, *Annona senegalensis* Pers., *Vitex doniana* Sweet, *Parkia biglobosa* (Jacq.) R.Br. ex G. Don, *Dichrostachys cinerea* (L.) Wight & Arn., *Pterocarpus erinaceus* Poir., *Pericopsis laxiflora* (Benth.) Meeuwen, *Daniellia oliveri* (Rolfe) Hutch. & Dalziel, *Vitellaria paradoxa* C.F. Gaertn., *Sarcocephalus latifolius* (Sm.) E.A. Bruce, *Uvaria chamae* P. Beauv., *Vitex grandifolia* Gürke and *Andropogon gayanus* Kunth (Biaou 2009; Armani et al. 2018).

The total population of the villages of Ewe and Adakplame is 13,623 individuals with 2,078 households (INSAE 2016). The main activity is agriculture, followed by hunting, livestock breeding and local commerce.

Sampling and data collection

The inventory of EARF plant species was conducted from February 2014 to December 2017. The forest investigation was based on a vegetation map divided into 250,000 m^2 (500 × 500 m) grids following 6 transects, each of 500 m width and 3000 m length. Transects were oriented south-north. The floristic sampling covered different components of the EARF (Fig. 1). At each stand, a topometer (Chaining Buddy, Fremaco Devices, Canada) with disposable filament was used to delimit quadrats of 10 × 50 m. The observation stands were set out at intervals of 100 m along each transect line and there was one quadrat per plot of 250,000 m^2. In total, 25 forest quadrats of 500 m^2 were floristically surveyed. To set a preliminary list of EARF flora, species identification was first based on our self-background during the sampling field work with photo captures (Olympus Digital Camera SP-620 UZ Silver and Samsung Galaxy S7 Android 6.0.1). This approach was combined with description session (on field and at the National Herbarium). Voucher specimens were systematically collected for specimens whose determination is confused. They were compared with voucher specimens of the national Herbarium. To access the systematic information notes, the botanical nomenclature followed the Analytical Flora of Benin (Akoègninou et al. 2006). The list of plant species recorded was compared to online resources such as the "Catalog of life" (Hassler 2020) and the Benin National Red List (Neuenschwander et al. 2011) in order to access botanical information notes and the conservation status of species.

Data analysis

The Angiosperm Phylogeny Group (APG IV 2009) and the legume subfamilies currently accepted by the legume phylogeny working group (LPWG 2017) were used to update the list of the vascular plants recorded in EARF. The taxonomic plant diversity was assessed in terms of species, genus, and family richness. The species richness (S) corresponds to the number of species recorded from sampling plots (n = 25). We used the functions "specpool" and "estimateR" in R software (R-Core-Team 2016) for the main reason that S is sensitive to sample size and this may introduce bias in our estimations based on the field record. To circumvent this, we use species accumulation curve and different estimation methods in order to appreciate in the case of our field study, the best estimator which is closest to our field record (Palmer 1990; Colwell and Coddington 1994; Chiu et al. 2014). This approach also helps to assess the completeness of our sampling effort. Chao, first order jackknife, second order jackknife and bootstrap were then used to estimate the total number of species surveyed and to draw species accumulation curves (R-Core-Team 2016; Oksanen et al. 2017).

Life forms assessment followed Raunkiaer (1934); Hutchinson and Dalziel (1954–1972): Ph: phanerophytes subdivided into meg: megaphanerophyte (> 30 m tall), mes: mesophanerophyte (8–30 m), mph: microphanerophyte (2–8 m), nph: nanophanerophyte (0.5–2 m); Ch: chamaephyte, Hc: hemicryptophyte; Th: therophyte; G: geophyte (Gb: with bulb, Gr: with rhizome and Gt: with tuber); Ep: epiphyte and their climbing forms L: liana (Lmph, Lnph and Lmes, LGr, LHc).

The Chorology types were established after Hutchinson and Dalziel (1954–1972) and White (1983), as follows: GC: Guineo-Congolean, SG: Sudano/Guinean transition, GE: Lower Guinean, GO: Upper Guinean, TA: Tropical Africa, AM: Afro-Malagasy, Pan: Pantropical.

Data resources

The data underpinning the analysis reported in this paper are deposited in the Dryad Data Repository at https://doi.org/10.5061/dryad.z8w9ghxbg (Houngnon and Adomou 2021).

Results

Floristics

Fig. 2A, B shows a panoramic view around and inside of EARF. Table 2 gives an overview of the vascular plant species recorded in the EARF. A total of 185 plant species distributed over 143 genera and 54 families was recorded (Table 2). With this figure, EARF conserves 6.59% of the national flora over 560.14 hectares of a community land. Of these, Rubiaceae was the most speciose family (20 species), followed by Fabaceae (15), Malvaceae (13), Apocynaceae (12), Sapindaceae (8) and Annonaceae (7). Capparaceae, Celastraceae, Dioscoreaceae, Putranjivaceae, Violaceae

Figure 2. Panoramic view of Ewe-Adakplame Relict Forest **A** forest ecosystem in contact with Ewe village's (Olympus photo A. Houngnon 2014) **B** forest gap with *Momordica charantia* carpet (Samung photo A. Houngnon 2016).

Table 2. Vascular plants of Ewe-Adapklame relict forest in Benin with their binomial, family life-forms and Chorotypes [Life-forms are meg: megaphanerophyte (> 30 m tall), mes: mesophanerophyte (8–30 m), mph: microphanerophyte (2–8 m), nph: nanophanerophyte (0.5–2 m); Ch: chamaephyte, Hc: hemicryptophyte; Th: therophyte; G: geophyte (Gb: with bulb, Gr: with rhizome and Gt: with tuber); Ep: epiphyte and their climbing forms L: liana (Lmph, Lnph and Lmes, LGr, LHc) and chorotypes are GC: Guineo-Congolean, SG: Sudano/Guinean transition, GE: Lower Guinean, GO: Upper Guinean, TA: Tropical Africa, AM: Afro-Malagasy and Pan: Pantropical].

Scientific name	Life forms	Chorology types	Voucher specimens
Acanthaceae			
Rhinacanthus virens (Nees) Milne. Readh. var. *virens*	Ch	GC	Houngnon 3860
Amaranthaceae			
Cyathula prostrata (L.) Blume	Th	Pan	Houngnon 3383
Amaryllidaceae			
Scadoxus multiflorus (Martyn) Raf. subsp *multiflorus*	Gb	TA	Houngnon 6724
Anacardiaceae			
Lannea nigritana (Sc. Elliot) Keay var. *nigritana*	mes	GO	De Souza 1971 a
Spondias mombin L.	mes	Pan	Maesen 7705
Annonaceae			
Artabotrys dahomensis Engl. & Diels.	Lnph	GE	Houngnon 97e
Artabotrys velutinus Sc. Elliot	Lnph	GC	Maesen 6612
Monanthotaxis parvifolia (Oliv.) Verdc.	Lnph	GE	Houngnon s.n.
Monodora tenuifolia Benth.	mph	GC	Éq. Bot. 105d
Uvariodendron angustifolium (Engl. & Diels) R.E.Fr	mph	GC	Houngnon 5571
Uvariopsis tripetala (Baker f.) G.E.Schatz Syn. *Dennettia tripetala* Baker f.	mph	GE	Akoègninou 2201
Xylopia longipetala De Wild. & T. Durand	mph	GC	Houngnon 4524
Apocynaceae			
Alafia barteri Oliv.	Lmph	GC	Chevalier 22841
Ancylobotrys scandens (Schumach. & Thonn.) Pifchon	Lmph	GC	Chevalier 23456
Baissea zygodioides (K. Schum.) Stapf	Lmph	GC	Houngnon 118c
Cryptolepis nigrescens (Wennberg) L. Joubert & Bruyns Syn. *Parquetina nigrescens* (Afzel.) Bullock	Lmph	GC	Le Testu 297
Holarrhena floribunda (G. Don) Dur. & Schinz	mph	TA	Houngnon 6574
Hunteria umbellata (K. Schum.) Hall. f. Syn. *H. eburnea* Pichon	mph	GC	Aké Assi 20284
Landolphia hirsuta (Hua) Pichon	Lmes	GC	Chevalier 23922
Marsdenia latifolia (Benth.) K. Schum.,	Lmph	TA	Akoègninou 5438
Mondia whitei (Hook. f.) Skeels	Lmph	TA	Adjakidjè 3007
Motandra guineensis (Thonn.) A. DC.	Lmph	TA	Adjanohoun 102
Saba thompsonii (A. Chev.) Pichon	Lmes	GC	Chevalier 22967
Secamone afzelii (Schultes) K. Schum.	Lmph	GC	Essou 3208
Araceae			
Anchomanes difformis (Blume) Engl. (Syn. *A. welwitschii* Rendle)	Gt	GC	Essou 1554
Cercestis mirabilis (N. E. Br.) Bogner Syn. *Rhektophyllum mirabile* N.E.Br.	Ep	GE	Akoègninou 3299.
Aristolochiaceae			
Pararistolochia goldieana (Hook. f.) Hutch. & Dalz.	LGr	GC	Houngnon 4605
Asparagaceae			
Dracaena arborea Bak	mph	GC	Maesen 6340
Asteraceae			
Chromolaena odorata (L.) R. King & H. Robinson	nph	AM	Sokpon B14
Gymnanthemum coloratum (Willd.) H. Rob. & B.Kahn	mph	SZ	Ayichédéhou 395
Laggera crispata (Vahl) Hepper & J. R. I. Wood.	Th	TA	Maesen 6746
Bignoniaceae			
Newbouldia laevis (P. Beauv.) Seem. ex Bureau	mph	GC	Houngnon 3087
Boraginaceae			
Ehretia cymosa Thonn.	mph	GC	Houngnon 5081
Cannabaceae			
Celtis mildbraedii Engl.	mes	GC	Essou 1648
Celtis philippensis Blanco Syn. *C. brownii* Rendle	mph	GC	Houngnon 2783

Scientific name	Life forms	Chorology types	Voucher specimens
Celtis zenkeri Engl.	meg	GC	Sokpon 852
Trema orientalis Syn. *T. guineensis*	mph	GC	Houngnon 1714d
Capparaceae			
Capparis brassii DC. Syn. *C. thonningii* Schum.	Lnph	GC	Maesen 6701
Capparis erythrocarpos Isert var. *erythrocarpos*	nph	GC	Esson 1087
Maerua duchesnei (De Wild.) F. White Syn: *Ritcheia duchesnei* (De Wild.) Keay	mph	GC	Houngnon 229a
Ritchiea capparioides (Andr.) Britten var. *capparoides*	Lnph	GC	Houngnon 4200
Ritchiea erecta Hook. f. Syn. *R. pentaphylla* Gilg & Bened.	nph	GE	Aké Assi 20288
Celastraceae			
Loeseneriella africana (Willd.) N.Hallé var. *africana* Syn. *Hippocratea Africana* (Willd.) Loes.	Lmph	Pan	Houngnon 6573
Reissantia indica (Willd.) N. Hallé	Lnph	Pan	Akoègninou 4026
Salacia longipes (Oliv.) N. Hallé	nph	TA	Akoègninou 3291
Salacia pallescens Oliv.	nph	GC	Sokpon 2221
Simicratea welwitschii (Oliv.) Syn. *S. welwitschii* (Oliv.) N. Hallé	Lmph	GC	Essou 1467
Combretaceae			
Combretum racemosum P. Beauv.	Lmph	GC	Le Testu 191
Commelinaceae			
Cyanotis lanata Benth.	Ch	SG	Morton A4570
Connaraceae			
Cnestis ferruginea Vahl ex DC.	nph	GC	Houngnon 3051
Cnestis corniculata Lam. Syn. *Cnestis longiflora* Schellenb.	Lmph	GO	Chevalier 22828
Rourea coccinea (Bak.) Jongkind syn. *Byrsocarpus coccineus* Thonn. & Schumach.	nph	TA	Chevalier 22798b
Convolvulaceae			
Calycobolus africanus (G. Don) heine	Lnph	GC	Adjakidjè 4111
Ipomoea mauritiana Hall. f.	Lmph	Pan	Oumorou 740
Cucurbitaceae			
Coccinia grandis (L.) Voigt	Lnph	GC	De Souza & Paradis 444a
Lagenaria breviflora (Benth.) Roberty Syn. *Adenopus breviflorus* Benth.	Lmes	TA	Houngnon 443a, 1518a
Luffa cylindrica (L.) M. J. Roem syn. *Luffa aegyptiaca* Mill	Lnph	Pan	Houngnon 453a
Momordica charantia L.	Lnph	GC	Houngnon 1676
Dichapetalaceae			
Dichapetalum madagascariense Poir. Syn. *D guineense* (DC.) Keay	Lmph	GC	Adomou 95
Tapura fischeri Engl.	mph	GC	Houngnon 1878a
Dioscoreaceae			
Dioscorea bulbifera L. var. bulbifera	Gt	Pan	Essoun 3316
Dioscorea lecardii De Wild.	Gt	SZ	Pauwels 8139
Dioscorea odoratissima Pax Syn. *D. praehensilis sensu* F.T.A, F.W.T.A	Gt	SG	Chevalier 24154
Dioscorea quartiniana A. Rich.	Gt	SZ	Sokpon 2329
Dioscorea sagittifolia Pax syn. *D. abyssinica* Hochst. ex Kunth	Gt	SZ	Paradis et Houngnon: 619d
Ebenaceae			
Diospyros abyssinica (Hiern) White	mes	GC	Houngnon 627b
Diospyros monbuttensis Gürke	mph	GC	Houngnon 629c
Diospyros soubreana F. White	nph	GC	Houngnon 2824
Euphorbiaceae			
Erythrococca anomala (Juss. ex Poir.) Prain	nph	GC	Houngnon 3345
Mallotus oppositifolius (Geisel.) Müell. Arg. var. *oppositifolius*	nph	AM	Adjakidjè & Akoègninou 590c
Tragia senegalensis Müll. Arg.	Lnph	SG	Adjakidjè 2803
Fabaceae			
Caesalpinoideae (Mimosoid clade)			
Acacia pennata (L.) Willd.	Lmph	TA	Essou 1672
Acacia polyacantha Willd. subsp. *Campylacantha* (Hochst. ex A. Rich.) Brenan	mes	SZ	Maesen 6703
Albizia adianthifolia (Schum.) W. Wight var. *adianthifolia*	mes	GC	Adjakidjè 4163
Albizia glaberrima (Schum. & Thonn.) Benth.	mph	GC	Houngnon 6532
Albizia ferruginea (Guill. & Perr.) Benth.	mes	GC	Paradis & Houngnon 933a

Scientific name	Life forms	Chorology types	Voucher specimens
Albizia zygia (DC.) J. F. Macbr.	mes	GC	Houngnon 936d
Mezoneuron benthamianum (Baill.) Herend. & Zarucchi	Lmph	GC	Paradis & Houngnon 277c
Detarioideae			
Detarium senegalense J.F. Gmel.	mes	GC	Houngnon 268[e]
Dialioideae			
Dialium guineense Willd.	mes	GC	Spire 118
Faboideae/ Papilionoideae			
Abrus precatorius L.	Lnph	Pan	Houngnon 1423g
Dalbergia lactea Vatke	Lmph	GE	De Souza & Paradis 1239e
Dalbergia melanoxylon Guill. Perr.	mph	SG	Adomou 167
Desmodium salicifolium (Poir.) DC. var. *salicifolium*	nph	GC	Frahm-Leliveld 57139
Dolichos trilobus	Lnph	SZ	Adomou 80
Millettia thonningii (Schum. & Thonn.) Bak.	mph	GC	Essou 1164
Icacinaceae			
Stachyanthus occidentalis (Keay & Miège) Boutique syn. *Neostachyanthus occidentalis* Keay & Miège	Lnph	GO	Essou 1102
Lamiaceae			
Clerodendrum capitatum (Willd.) Schum. & Thonn.	Lmph	GC	Lisowski 0-929
Hoslundia opposita Vahl	nph	AM	Pauwels 8286
Premna quadrifolia Schum. & Thonn.	nph	GO	Sokpon 1068
Vitex micrantha Gürke*	mes	GC	Adomou s.n.
Linaceae			
Hugonia platysepala Welw. ex Oliv.	Lmph	GC	Paradis & Houngnon 831a
Loganiaceae			
Strychnos barteri Soler.	Lmes	GC	Paradis & Houngnon 838a
Strychnos floribunda Gilg	Lmes	GC	Maesen 6821
Strychnos nigritana Bak.	Lmes	GC	Akoègninou 3289
Strychnos splendens Gilg	Lmes	GC	Houngnon 835b
Malvaceae			
Abutilon mauritianum (Jacq.) Medic.	Ch	TA	De Souza & Paradis 851a
Ceiba pentandra (L.) Gaertn.	meg	Pan	Houngnon 188a
Hibiscus lunariifolius Willd.	Lmph	Pan	Adomou s.n.
Hibiscus owariensis P. Beauv.	nph	GC	Paradis et Houngnon 856a
Cola milfenii K. Schum.	mph	GC	Houngnon 4399
Glyphaea brevis (Spreng.) Monachino	mph	GC	Houngnon 2036[e]
Grewia carpinifolia Juss.	mph	GC	Houngnon 1446f
Mansonia altissima (A. Chev.) A. Chev. var. *altissima**	mes	GC	Houngnon 1309a ; 4322
Nesogordonia papaverifera (A. Chev.) syn *N. kabengaensis* (K.Schum.)*	mph	GC	Houngnon 13l0a
Octolobus spectabilis Welw. Syn. *O. angustatus* Hutch.*	nph	GC	Adomou s.n.
Pterygota macrocarpa K. Schum *.	mph	GC	Houngnon 4321
Sterculia tragacantha Lindl.	mes	GC	De Souza & Houngnon 188d
Triplochiton scleroxylon K. Schum.	meg	GC	Chevalier 22819
Melastomataceae			
Memecylon afzelii G. Don var. *afzelii*	Lnph	GC	Houngnon 897c
Warneckea memecyloides (Benth.) Jac. Fél Syn. *Memecylon memecyloides* (Benth)	Lmph	GC	De Souza & Paradis 900a
Meliaceae			
Trichilia prieureana A. Juss. subsp. *prieureana*	mph	GC	Adomou 90
Menispermaceae			
Dioscoreophyllum cumminsii (Stapf) Diels	Lnph	GC	Houngnon 919a
Rhigiocarya racemifera Miers	Lnph	GC	Maesen 6820
Tiliacora funifera (Miers) Oliv.	Lmph	GC	De Souza 92li
Triclisia subcordata Oliv.	Lnph	GC	Sokpon 31

Scientific name	Life forms	Chorology types	Voucher specimens
Moraceae			
Antiaris toxicaria Lesch.	meg	GC	Essou 1547
Ficus recurvata De Wild. Syn. *Ficus goliath* A. Chev.	mes	GC	Adomou s.n.
Ficus ovata Vahl,	Ep	GC	Adomou s.n.
Milicia exelsa (Welw.) Berg Syn. *Chlorophora excelsa* (Welw.) benth.	meg	GC	Chevalier 23169
Olacaceae			
Olax subscorpioidea Oliv. var. *subscorpioidea*	mph	GC	Houngnon 7652
Oleaceae			
Schrebera arborea A. Chev.	mes	GC	Akoègninou 2187
Opiliaceae			
Opilia amentacea Roxb. Syn. *O. celtidifolia* (Guill. & Perr) Endl.,	Lmph	SZ	Adjakidjè 1477
Pandaceae			
Microdesmis keayana J. Léonard, syn. *M. puberula* Hook. f.	mph	GC	Pauwels 8298
Passifloraceae			
Adenia cynanchifolia (Benth.) Harms	Lmph	GE	Adomou s.n.
Adenia lobata (Jacq.) Engl.	Lmph	GC	Essou 1637
Phytolaccaceae			
Hilleria latifolia (Lam.) H. Walt.	Ch	AM	Adomou 129
Poaceae			
Acroceras gabunense (Hack.) Clayton*	Th	GC	Mission *ACCT/Bénin 2165*
Olyra latifolia L.	nph	GC	Houngnon 720c
Oplismenus hirtellus (L.) P. Beauv. subsp. *Hirtellus*	Ch	SG	De Souza & Paradis 722a
Streptogyna crinita P. Beauv.	Gr	GC	Houngnon 765b
Polygalaceae			
Carpolobia lutea G. Don	mph	GC	Maesen 6617
Putranjivaceae			
Drypetes aframensis Hutch.*	mph	GO	Adomou s.n.
Drypetes afzelii (Pax) Hutch.,*	mes	GO	Houngnon 177 la
Drypetes floribunda (Müll. Arg.) Hutch.	mph	GC	Houngnon 4266
Drypetes gilgiana (Pax) Pax & Hoffm.*	nph	GC	Akoègninou 2196
Drypetes leonensis Pax,*	mes	GC	Houngnon 1771b
Rhamnaceae			
Lasiodiscus mannii Hook. f.	mph	GC	Houngnon 1329b
Rubiaceae			
Aidia genipiflora (DC.) Dandy	mph	GC	Maesen 6611
Chassalia kolly (Schumach.) Hepper	nph	GC	Maesen 6358
Coffea ebracteolata (Hiern) Brenan	Lnph	GC	Lejoly&Ganglo 2
Cremaspora triflora (Thonn.) K. Schum.	Lmph	GC	Maesen 6284
Leptactina involucrata Hook. f.	Lnph	GC	Adomou s.n.
Gardenia nitida Hook.	mph	GC	Adomou 73
Hymenodictyon floribundum (Steud. & Hochst.) B.L.Rob.	mes	GC	Sinsin 2863
Keetia hispida (Benth.) Bridson	Lmph	GC	Adomou s.n.
Morinda lucida Benth.	mph	Pan	Maesen 6651
Oxyanthus pallidus Hiern	nph	GC	Adomou s.n.
Oxyanthus speciosus DC. subsp. *speciosus*	nph	GC	Essou 2496
Pavetta corymbosa (DC.) F. N. Williams	mph	SG	Sokpon 1884
Pouchetia africana DC.	nph	GC	Houngnon 6659
Psydrax horizontalis (K. Schum. & Thonn.) Bridson	Lmph	SG	Maesen 6710
Psydrax parviflora (Afzel.) Bridson	nph	GO	Maesen 6287
Rothmannia longijlora Salisb	mph	GC	Le Teslu 101
Rothmannia urcelliformis (Hiern) Bullock ex Robyns	mph	GC	Dansi TW 50799
Rytigynia canthioides (Benth.) Robyns	mph	GC	Adomou s.n.
Vangueriella nigerica (Robyns) Verdc. Syn. *Vangueriopsis nigerica* Robyns	mph	SZ	Maesen 6315
Vangueriella spinosa (Schumach.&Thonn.)Verdc. Syn. *Vangueriopsis spinosa* Hepper	mph	SZ	Adomou 32
Rutaceae			
Zanthoxylum leprieurii Guill. & Perr. Syn. *Fagara angolensis* Engl.	mph	GC	Houngnon 535a
Zanthoxylum zanthoxyloides (Lam.) Zepernick & Timber	mph	SG	Essou 2396

Scientific name	Life forms	Chorology types	Voucher specimens
Salicaceae			
Dovyalis zenkeri Gilg (+) Syn. *D. afzelii* Gilg. (+)	nph	GO	Houngnon 1364a
Flacourtia indica (Burm. f.) Merr. Syn. *Flacourtia flavescens* Willd.	mph	GC	Houngnon 6606
Sapindaceae			
Allophylus africanus P. Beauv.	mph	GC	Houngnon 4037
Allophylus spicatus (Poir.) Radlk.	mph	GC	Houngnon 4037
Blighia sapida Koenig	mPh	Pan	Houngnon 5472
Blighia unijugata Bak.	mph	GC	Paradis & Houngnon 1693d
Deinbollia pinnata (Poir.) Schumach. & Thonn.	nph	GC	Maesen 6397
Lecaniodiscus cupanioides Planch.	mph	GC	Maesen 6310
Majidea forsteri (Sprague) Radlk.	meg	GC	Houngnon 1254a
Pancovia bijuga Willd.	mph	GC	Houngnon 4978
Sapotaceae			
Chrysophyllum welwitschii Engl.* (+)	Lnph	GC	Adomou s.n.
Englerophytum oblanceolatum (S.Moore) T.D.Penn. syn. *Bequaertiodendron oblanceolatum** (S.Moore) Heine & J. H. Hemsl.	nph	TA	Maesen 6154
Pouteria alnifolia (Baker) Roberty Syn. *Malacantha alnifolia* (Baker)	mph	GC	Sokpon 1915
Smilacaceae			
Smilax anceps Willd.Syn. *S. kraussiana* Meissner	LGr	TA	Chevalier 24225
Solanaceae			
Solanum terminale Forssk. Subsp inconstans (C.H. Wright) Heine	Lmph	GC	Yédomonhan 173
Ulmaceae			
Chaetachme aristata Planch.	mph	GC	Houngnon 1784c
Violaceae			
Rinorea batesii Chipp, Kew Bull. 293 (1923).	nph	GC	Adomou 83
Rinorea brachypetala (Turcz.) Kuntze	nph	GC	Adomou s.n.
Rinorea dentata (P.Beauv.) Kuntze	mph	GC	Houngnon
Rinorea ilicifolia (Welw. ex Oliv.) Kuntze *	nph	GC	Adomou 109
Rinorea kibbiensis Chipp.	nph	GC	Paradis & Houngnon 1347a
Vitaceae			
Cissus glaucophylla Hook. f.	Lnph	GC	Adomou s.n.
Cissus petiolata Hook. f.	Lnph	GC	Adjakidjè 2976
Cissus populnea Guill. & Perr. var. *populnea*	LHc	SZ	Houngnon 68d
Cissus quadrangularis L.	Lmph	SZ	Houngnon 5105

*: Plant species restricted to Ewe Adakplame Relict Forest (+): Non recorded

were each represented by five species. Among the 185 vascular plants of EARF 12% of the families (22) were represented by one species each. The genera *Dioscorea*, *Drypetes and Rinorea*, are represented by five species followed by genera *Albizia*, *Cissus*, *Strychnos* (4 species each) and *Celtis* and *Diospyros* (3 species each). EARF also provides habitat for *Chrysophyllum welwitschii*, (Not mentioned in the Flora), *Cissus glaucophylla* (Not mentioned in the Flora), *Drypetes aframensis*, (Not mentioned in the Flora), *Drypetes afzelii*, *Drypetes gilgiana*, *Drypetes leonensis*, *Englerophytum oblanceolatum*, *Mansonia altissima*, *Nesogordonia papaverifera*, *Octolobus spectabilis*, (Not mentioned in the Flora), *Rinorea batesii*, *Rinorea brachypetala* (Not mentioned in the Flora), *Rinorea dentata*, *Rinorea ilicifolia*, *Rinorea kibbiensis*, *Vitex micrantha*), (Not mentioned in the Flora) which appear to be confined to EARF that can be seen as the single location of their occurrence in Benin. Table 2 also describes the community data set using family, binomial, life-forms and Chorotypes. Some of these plant species are featured in Fig. 3A–K.

Figure 3. Common species of Ewe-Adakplame Relict Forest **A** *Drypetes gilgiana* (Photo of Alfred Houngnon 2017) **B** *Triplochiton scleroxylon* (Samsung photo A. Houngnon 2017) **C** *Englerophytum oblanceolatum* (Olympus photo A. Houngnon 2014) **D** *Mansonia altissima* (Olympus photo A. Houngnon 2014) **E** *Uvariopsis tripetala* **F** *Ceiba pentandra* (Olympus photo A. Houngnon 2014) **G** *Anchomanes welwitschii* (Samsung photo A. Houngnon 2015) **H** *Abrus precatorius* (Samsung photo A. Houngnon 2016) **I** *Vitex micrantha* (Samsung photo A. Houngnon 2016) **J** *Momordica charantia* (Samsung photo A. Houngnon 2016) **K** *Dioscoreophyllum cumminsii* (photo A. Adomou 2011).

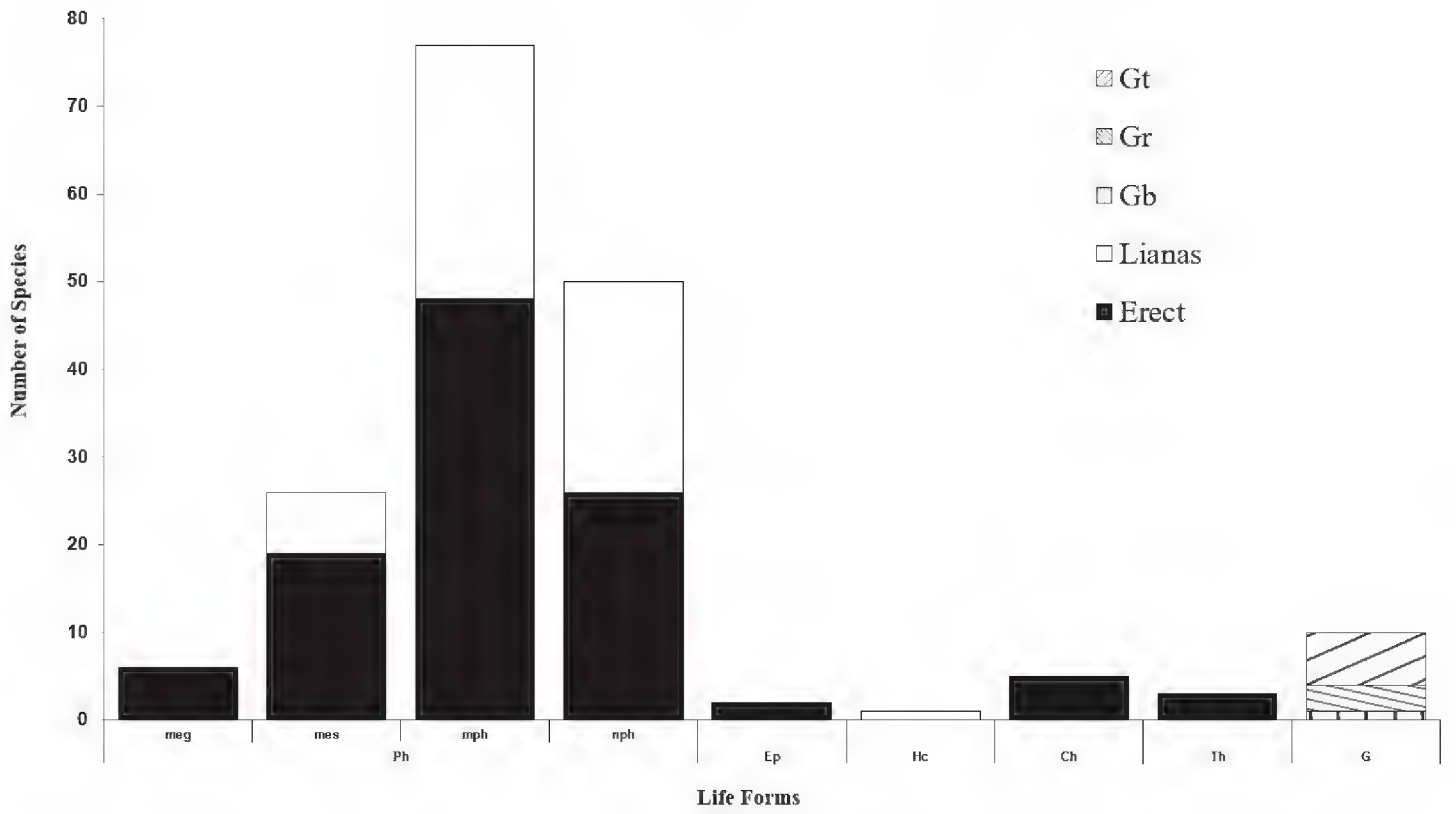


Figure 4. Life form spectrum of the Ewe-Adakplame relict forest. Erects are represented by Ph: Phanerophytes including megaphanerophytes (meg), mesophanerophytes (mes), microphanerophytes (mph), nanophanerophytes (nph), G: Geophytes are: Gb: with bulb, Gr: with rhizome and Gt: with tuber Ch: Chamaephytes, Th: Therophytes, Ep: Epiphytes, Hc: Hemicryptophytes. Climbing forms are L: Lianas (mph, nph and mes, Gr, Hc).

Life form spectrum

The most common life forms were phanerophytes (88%), containing, 3% of mega phanerophytes (meg) which are very large forest trees, 14% of mesophanerophytes (mes) or medium-sized forest trees, 43% of microphanerophytes (mph) or small forest trees and 28% of shrubs gathered into nanophanerophytes (nph). We recorded 33% of lianas, 6% of geophytes and 6% for chamaephyte, therophyte, epiphyte, hemicryptophyte (Fig. 4). The microphanerophytes were most representative among phanerophytes. The tree layer was discontinuous and composed of *Celtis mildbraedii* (Cannabaceae), *Triplochiton scleroxylon* (Malvaceae), *Antiaris toxicaria* (Moraceae), *Celtis zenkeri* (Cannabaceae), *Dialium guineense* (Fabaceae), *Ceiba pentandra* (Malvaceae), *Mansonia altissima* (Malvaceae), *Milicia exelsa* (Moraceae), and *Nesogordonia papaverifera* (Malvaceae).

Chorology of Ewe-Adakplame relict forest

The most representative chorotypes (Fig. 5) included Guineo-Congolean species (66%), followed by 14% of wide distribution species including Tropical Africa (TA) and Pantropical (Pan) plant species. Upper Guinea species included plants such as *Uvariopsis tripetala* Syn. *Dennettia tripetala* (Annonaceae), *Drypetes aframensis* (Putranjivaceae tribe Drypeteae), *Stachyanthus occidentalis* Syn.

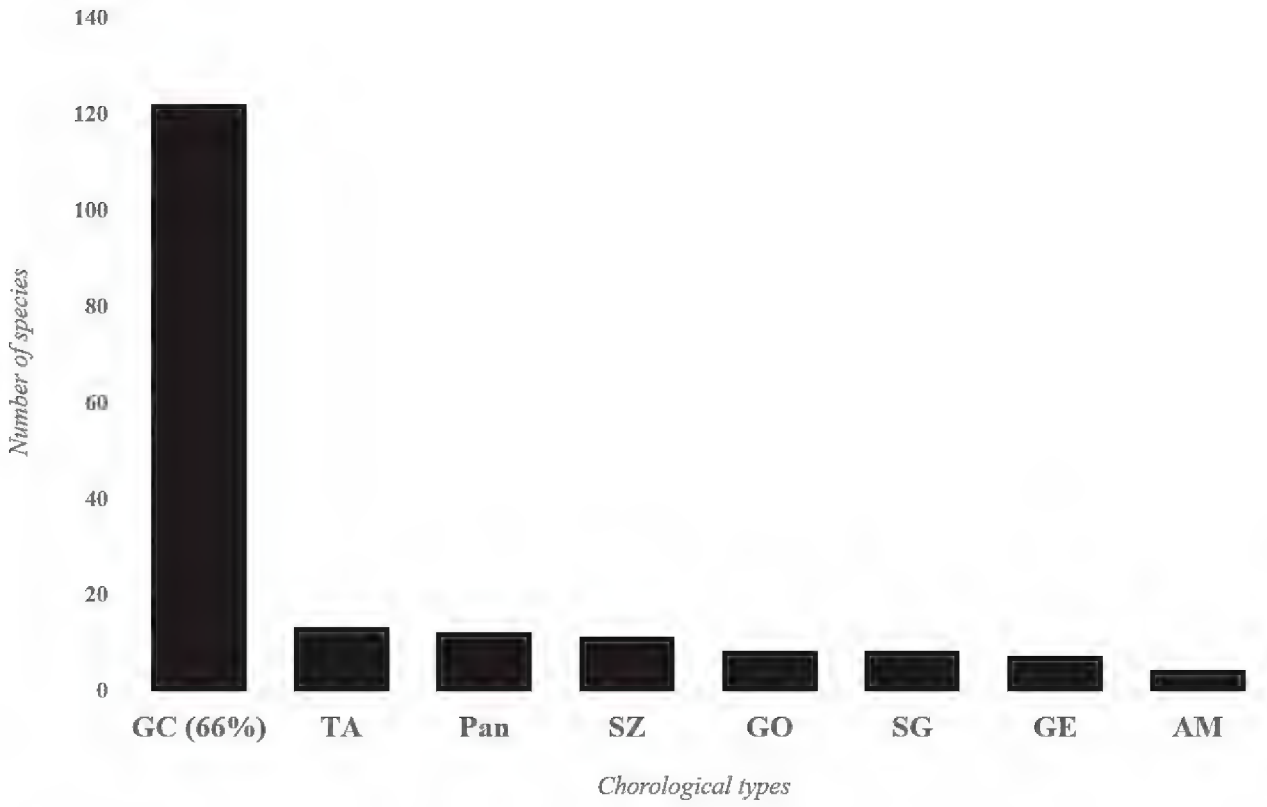


Figure 5. Chorological spectrum of the Ewe-Adakplame Relict Forest. GC: Guineo-Congolean, SG: Sudano/Guinean transition, GE: Lower Guinean, GO: Upper Guinean, TA: Tropical Africa, AM: Afro-Malagasy and Pan: Pantropical.

Neostachyanthus occidentalis (Icacinaceae), *Lannea nigritana* var. *nigritana* (Anacardiaceae), *Psydrax parviflora* (Rubiaceae), *Premna quadrifolia* (Lamiaceae), *Cnestis corniculata* (Connaraceae). *Monanthotaxis parvifolia* (Annonaceae), *Artabotrys dahomensis* (Annonaceae), *Dalbergia lactea* (Fabaceae – Faboideae), *Ritchiea erecta* Syn. *R. pentaphylla* (Capparaceae) and *Cercestis mirabilis* Syn. *Rhektophyllum mirabile* (Araceae) are among Lower Guinea species.

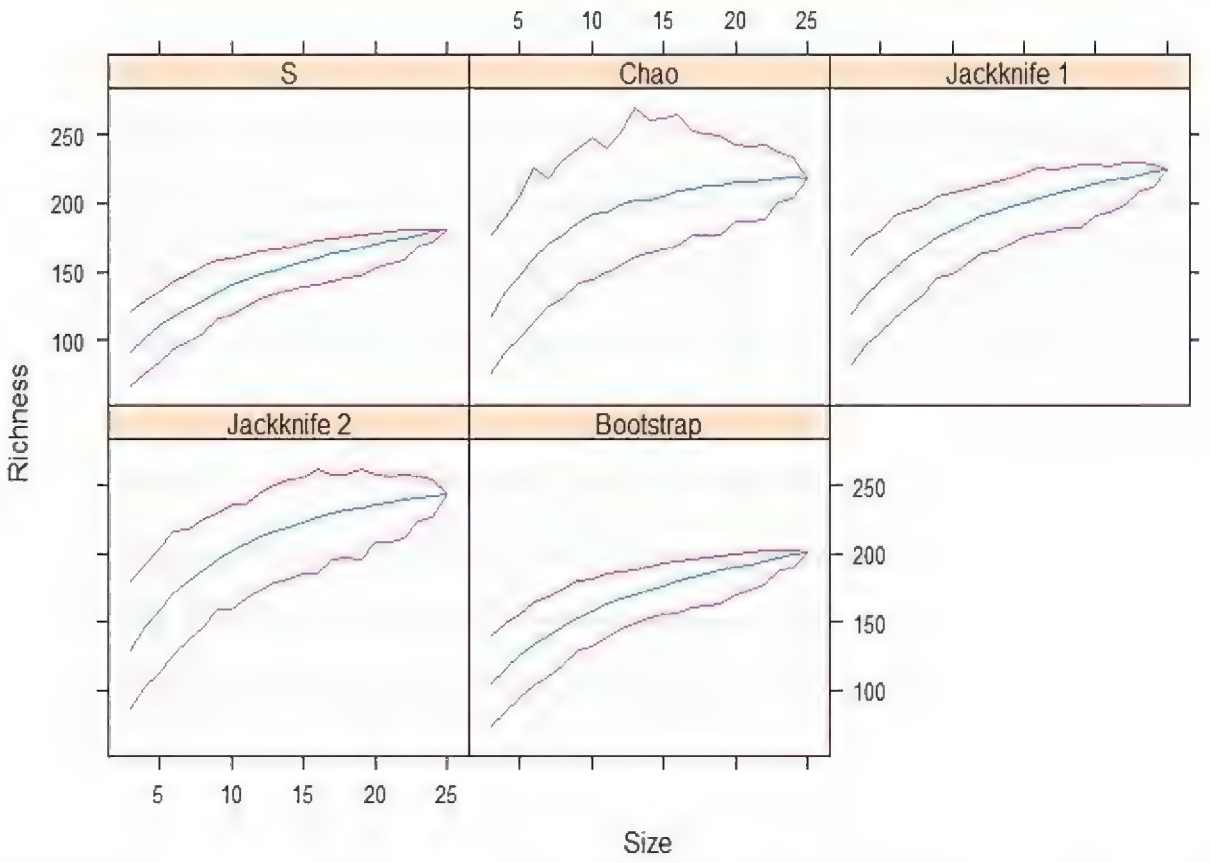
Species richness estimations

The counted number of plant species for the EARF was 185. This corresponds to the species richness (S) or the number of species that has been recorded from plot sampling and listed in Table 2. The species richness estimations as per *Bootstrap*, *Chao*, *Jacknife1* and *Jacknife2* were respectively 200.52 ± 9.2808; 217.62 ± 14.5972, 224.16 ± 15.3725 and 242.67. We can see that the species richness estimates differ strongly giving a range of 200.52–242.67 species. The species accumulation curves in Fig. 6 show that they were hardly tending towards the asymptote and are still climbing at the right-hand end signifying that the sampling effort was insufficient. This suggests that the sampling has not captured nearly all the species in EARF and that many species were missed (on average approximately 16 species (± 9.2808) for *Bootstrap*, 33 species (± 14.5972) for *Chao*, 39 species (± 15.3725) for *Jacknife1* and 58 species for *Jacknife2*.

Discussion

The Ewe-Adakplame Relict Forest corresponds to the semi-deciduous forest type, which was described in Benin as the only *Drypetes aframensis-Nesogordonia papaverifera* community (Adomou et al. 2009). Guineo-Congolean species are abundant (66%) although the EARF is located in a matrix of savanna-dominated vegetation. Guineo-Congolean species accounted for 33% in riparian forests of Benin (Natta 2003), 61.7% in gallery forests of the Hippopotamus Pond Biosphere Reserve at Burkina Faso (Bélem and Guinko 1998), and 70 to 75% in gallery forests at Lamto (southern Côte d'Ivoire) (Devineau 1975). The overall plant species composition makes EARF floristically comparable to the moist semi-deciduous forest of Nigeria (Lower Guinea) (Richards 1939) and the *Celtis* spp.-*Mansonia altissima* community of Côte d'Ivoire (Upper Guinea) (Guillaumet and Adjanohoun 1971). Guillaumet and Adjanohoun (1971) also pointed out that the dominance of Cannabaceae (previously Ulmaceae) and Malvaceae (previously Sterculiaceae) in the Upper and Lower Guinea forests offers evidence that West African semi-deciduous forests are at climatic climax. These indicator families were also reported as characteristics of the semi-deciduous forests in Ghana (Vooren and Sayer 1992) and Côte d'Ivoire (Swaine 1996) within the Upper Guinea zone. This high proportion of Guineo-Congolean species shows the floristic uniqueness of EARF and highlights its great importance in Benin which landscape is savanna dominated.

Unlike Palmer (1990) who showed that *Jack 1* is the most precise and least biased, it is rather the *Bootstrap* estimator (200.52 ± 9.2808) that seems to be closer to our field results (S = 185 species). The *Bootstrap* value is also close to estimates of Adomou et al. (2010) who assessed the specific richness of EARF around 200 species. This is what justifies the calculation of the four estimation methods (*Chao*, *first order jackknife*, *second order jackknife and bootstrap*) and not only one as Palmer (1990) would have demonstrated. In our study, the species accumulation curves were calculated with estimators (*Chao*, *Jack 1*, *Jack 2* and *Bootstrap*) and showed a change in species richness without flatten off at the right hand. The *Bootstrap* appears to be the best estimator which is closest to EARF plant richness estimated by Adomou et al. (2010). The Fig. 6 show that species accumulation curves were hardly tending towards the asymptote and are still climbing at the right hand end signifying that the sampling effort was insufficient. This suggests that the sampling did not capture all the species in EARF. The shape of the species accumulation curves should plateau for large numbers of sites sampled. However, the number of observed species will typically be smaller than the true number of species. Since species richness depends on sample size, we can expect that we will not have recorded all the species that occur in the survey area. So, the Species accumulation curves were used to ascertain range in values obtained with the different methods and we can expect that the correct total richness lies somewhere within that range. Many species will always remain unseen or undetected in a



Number of observation (N)	Richness observed (S)	Chao	Chao.se	Jack1	Jack1.se	Jack2	Boot	Boot.se
25	185	217.62	14.5972	224.16	15.3725	242.67	200.52	9.2808

Figure 6. Species richness and richness estimations (Chao, first order jackknife, second order jackknife and bootstrap) (y-axis) in relation to sample size (x-axis) at the Ewe-Adakplame relict forest.

collection of sample plots. It is like the case of *Chrysophyllum welwitschii* (Sapotaceae) and *Drypetes aframensis* which, although reported in EARF (Adomou 2005), has not been recorded since 2014. *Drypetes aframensis* (Salicaceae) is also not mentioned in the Benin Flora. From a physiognomic point of view, it is important to underline that it is sometimes extremely difficult to survey some areas because of the thickness of the vegetation which can be very inaccessible. Other places are severely affected by human presence leading to very sparse vegetation or gap areas in the heart of the forest with completely isolated forest tree species. This is also the case of the periphery cleared by human boundaries encroachment and so many activities often carried out illegally. These constraints have often influenced the layout and the number of sampled sites. This also proves that despite the botanical sampling effort of Benin (Sosef et al. 2017), some priority species for conservation have either not yet been collected or reported and therefore could be omitted.

The connection of EARF with the West African forests blocks located on both side of the Dahomey Gap is emphasized here by the high proportion of Guineo-Congolean species recorded (66%). The high rate of phanerophytes and their phytochories testifies to the floristic originality of EARF in a crop and savanna dominated landscape. This justifies the physiognomic and floristic links of EARF with the two Guinean and Congolia forest blocks and substantiates the hypothesis that EARF is a remnant of the

dense forests which were once a continuous block from west to central Africa as demonstrated by numerous palynological studies (Tossou 2002; Salzmann and Hoelzmann 2005) and also phylogeography (Demenou et al. 2016). The floristic link of the EARF with the West African semi-deciduous forest is also best highlighted by the high representation of many Upper Guinean endemic species belonging to the families of Cannabaceae (*Celtis mildbraedii*, *C. zenkeri* and *C. prantlii*), Malvaceae (*Triplochiton scleroxylon*, *Nesogordonia papaverifera*, *Mansonia altissima*, *Pterygota macrocarpa*, *Octobolus spectabilis* and *Sterculia tragacantha*), and Putranjivaceae (*Drypetes floribunda*, *D. gilgiana* and *D. aframensis*). This record provides strong evidence for past floristic connections with the West African rain forest zone which is consistent with paleovegetation reconstructions indicating that the tropical African rain forest formed a single block during the Holocene Humid Period (c. 9000–4500 yr BP) (Tossou 2002; Salzmann and Hoelzmann 2005; Demenou et al. 2018). Furthermore, the richness of EARF in *Rinorea* species (*R. batesii*, *R. brachypetala*, *R. dentata*, *R. kibbiensis* and *R. ilicifolia*) and their abundance are unique in the country. According to Akoègninou et al. (2006), *Rinorea batesii* Chipp, *Rinorea ilicifolia* (Welw. Ex OIiv.) Kuntze, *Rinorea dentata* are common in West, Central and East Africa and some of them in Madagascar. However, in Benin most of them are rare and are only found in EARF. *Rinorea brachypetala*, although it has been reported by Adomou (2005), was not mentioned in the National Flora (Akoègninou et al. 2006). *Rinorea* species are described as good indicators for West African semi-deciduous forests in a climax state (Achoundong 2000). The strong representation of *Rinorea* spp., the Cannabaceae (previously Ulmaceae) and the Malvaceae (previously Sterculiaceae) substantiate the view of Guillaumet and Adjanohoun (1971), who considered this forest type as the climatic climax or primeval type of semi-deciduous forest in West Africa. With this floristic composition, EARF can be seen as a unique West African rain forest refuge in a matrix of savanna-dominated vegetation in Benin.

In contrast, the surrounding vegetation at the immediate edge of EARF is composed of savanna species (Fig. 7A–J) from the Guineo-Sudanian transition zone such as: *Adansonia digitata* L. (Malvaceae), *Stereospermum kunthianum* Cham. (Bignoniaceae), *Trichilia emetic* Vahl (Meliaceae), *Annona senegalensis* Pers. (Annonaceae), *Vitex doniana* Sweet (Lamiaceae), *Parkia biglobosa* (Jacq.) R.Br. ex G. Don (Fabaceae-Caesalpinioideae (mimosoid clade)), *Dichrostachys cinerea* (L.) Wight & Arn. (Fabaceae- Caesalpinioideae (mimosoid clade)), *Pterocarpus erinaceus* Poir. (Fabaceae-Faboideae), *Pericopsis laxiflora* (Benth.) Meeuwen (Fabaceae-Faboideae), *Daniellia oliveri* (Rolfe) Hutch. & Dalziel (Fabaceae-Detarioideae), *Sarcocephalus latifolius* (Sm.) E.A. Bruce (Rubiaceae) and *Andropogon gayanus* Kunth (Poaceae). The landscape is characterized by two basin ecosystems with clear dissimilarity combining forest/savanna and crop areas in stable equilibrium (Figs 8A, B). This makes EARF a special site of rich biodiversity and emphasizes the vital role the forest plays as a corridor of transition conducive to resilience and the flow of genes for ecosystem equilibrium.

Figure 7. Species collected in the surrounding zone of Ewe-Adakplame Relict Forest **A** *Adansonia digitata* (Samsung photo A. Houngnon 2015) **B** *Pericopsis laxiflora* (Samsung photo A. Houngnon 2016) **C** *Trichilia emetic* (Samsung photo A. Houngnon 2016) **D** *Annona senegalensis* (Olympus photo A. Houngnon 2014) **E** *Vitex doniana* (Samsung photo A. Houngnon 2016) **F** *Parkia biglobosa* (Samsung photo A. Houngnon 2016) **G** *Dichrostachys cinerea* (Samsung photo A. Houngnon 2016) **H** *Pterocarpus erinaceus* (Samsung photo A. Houngnon 2016) **I** *Daniellia oliveri* (Samsung photo A. Houngnon 2016) and **J** *Andropogon gayanus* (Samsung photo A. Houngnon 2017).

In total, we counted thirteen species restricted to one site in EARF. This is higher than the nine species previously reported by Adomou et al. (2010) in the EARF. Our record represents 15.4% of species with high conservation priority, thus describing

Figure 8. Ewe Adakplame Relict Forest in a matrix of savanna and agriculture landscape **A** forest edge affected by anthropogenic activities (Samsung photo A. Houngnon 2017) **B** Landscape of fallow and field around the edge of the forest ecosystem (Olympus photo A. Houngnon 2016).

EARF as being one of the richest sites in range-restricted plant species of Benin. This increase in range-restricted species can be explained by the fact that species with a high scarcity index are vulnerable and could disappear if biodiversity sanctuaries that protect them disappear (Juhé-Beaulaton 2010). Indeed, during the last three decades in Benin, some forests areas have been cleared with an annual degradation rate of 70,000 hectares per year (PNF Bénin 2004). This habitat loss has considerably narrowed the survival places where rare species were previously recorded.

Some of these species found in the single location of EARF within Benin (e.g., *Acroceras gabunense*, *Chrysophyllum welwitschii*, *Dovyalis afzelii*, *Drypetes aframensis*, *Drypetes gilgiana*, *Englerophytum oblanceolatum*, *Mansonia altissima*, *Nesogordonia papaverifera*, *Octolobus spectabilis*, *Pterygota macrocarpa*, *Rinorea ilicifolia*, *Rinorea kibbiensis* and *Vitex micrantha*) may gain more attention in the National Red List (Neuenschwander et al. 2011). Among them, there are many globally threatened species as the case of *Nesogordonia papaverifera* and *Mansonia altissima*, respectively reported as vulnerable (VU) and endangered (EN) by IUCN (2002) and later, were both assessed in Benin as critically endangered (CR) by Adomou et al. (2010) who considered EARF as sites with high concentration of threatened plant species in Benin. Moreover, the impact of harvesting on the survival of the most endangered species has been long ignored while many of them are not domesticated and many species uncharacterized. The case of *Mansonia altissima* is of urgent concern because its population is almost completely depleted, since it is locally used for roofing poles. *Englerophytum oblanceolatum* (Sapotaceae), which is not listed on the National Red List of Benin also tends to be concentrated in EARF (Houngnon 2014). Unfortunately, most of Benin Forest is still under severe threat due to expansion of towns, agricultural and fallow (Oloukoï et al. 2007) that are narrowing the natural habitat and leading to a massive loss of many of the local biodiversity taxa. To this end, since 2014, we have been trying to raise awareness among local communities from the villages of Ewe and Adakplame through participative action toward nursery establishment (Houngnon 2014) and vegetative propagation of native tree (Houngnon 2015) in order to rehabilitate the degraded lands and areas that could potentially be sensitive for the EARF durability.

Conclusion

The importance of the flora of EARF testifies to its role in conserving forest biodiversity in the Dahomey gap corridor. This justifies its peculiarity and the relevance of this baseline vegetation information that could be used as complete range taxa that may allow us to test the forest refuge hypothesis against alternative speciation models across ecological gradients. As it happens, the management of the forest of this type, also raises the question of deepening interactions linking human environment in order to better understand the actual role that humans would have played in shaping ecosystems in the Dahomey gap since millennia. So, it would be interesting to understand the interplay between locals and EARF in order to explain its persistence in this savanna dominated landscape. Therefore, the actions to be considered following this checklist of EARF must take into account the community's engagement in rehabilitating the degraded lands inside and around EARF.

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References

Achoundong G (1996) Les *Rinorea* comme indicateurs des grands types forestiers du Cameroun. In: van der Maesen LJG, van der Burgt XM, van Medenbach de Rooy JM (Eds) The Biodiversity of African Plants. Kluwer Academy Publishing, The Netherlands, 536–544. https://doi.org/10.1007/978-94-009-0285-5_69

Achoundong G (2000) Les *Rinorea* et l'étude des refuges forestiers en Afrique. In: Servant M, Servant-Vildary S (Eds) Dynamique à long terme des écosystèmes forestiers intertropicaux. Mémoire UNESCO, Paris, 19–29.

Adjanohoun E (1966) Existence au Dahomey de savanes côtières analogues à celles de la Côte d'Ivoire. Etudes dahoméennes 6–7: 48–71.

Adjanohoun E, Adjakidjè V, Ahyi MRA, Aké Assi L, Akoègninou A, Dalmeda J, Akpovo F, Boukef K, Chadaré F, Cusset G, Dramane K, Eyme J, Gassita J-N, Gbaguidi N, Goudoté E, Guinko S, Houngnon P, Issa L, Keita A, Kiniffo HV, Koné Bamba D, Musampa Nseyya A, Saadou N, Sodogandji TH, De Souza S, Tchabi A, Zinsou Dossa C, Zohoun Th (1989) Contribution aux études ethnobotaniques et floristiques en République Populaire du Bénin. ACCT, Paris, 895 pp.

Adomou A (2005) Vegetation patterns and environmental gradients in Benin. PhD thesis. Wageningen University, Wageningen, 133 pp.

Adomou AC, Sinsin B, van der Maesen JLG (2006) Phytosociological and chorological approaches to phytogeography: A meso-scale study in Benin. Systematics and Geography of Plants 76: 155–178.

Adomou AC, Akoègninou A, Sinsin B, de Foucault B, van der Maesen JLG (2009) Semi-deciduous forest remnants in Benin: Patterns and floristic characterization. Acta Botanica Gallica 156(2): 159–171. https://doi.org/10.1080/12538078.2009.10516148

Adomou AC, Sinsin B, Akoégninou A, van der Maesen JLG (2010) Plant species and ecosystems with high conservation priority in Benin. In: van der Burgt X, van der Maesen J, Onana J-M (Eds) Systematics and Conservation of African Plants. Royal Botanic Gardens, Kew, 429–444.

Akoègninou A, van der Burg WJ, van der Maesen LJG (2006) Flore analytique du Bénin. Backhuys Publishers, Leiden, 1034 pp.

APG IV (2009) An Update of the Angiosperm Phylogeny Group Classification for the Orders and Families of Flowering Plants: APG III. Botanical Journal of the Linnean Society 161(2): 105–121. https://doi.org/10.1111/j.1095-8339.2009.00996.x

Armani M, Langevelde FV, Tomlinson KW, Adu-Bredu S, Djagbletey GD, Veenendaal EM (2018) Compositional patterns of overstorey and understorey woody communities in a forest–savanna boundary in Ghana. Plant Ecology & Diversity 11(4): 451–463. https://doi.org/10.1080/17550874.2018.1539133

Aubréville A (1937) Les forêts du Dahomey et du Togo. Bulletin de communication et Histoire des Sciences en Afrique Occidentale Française 20: 1–112.

Bani G (2006) Monographie de la Commune de Kétou. Afrique Conseil, Cotonou.

Bélem OM, Guinko S (1998) La biodiversité des galleries forestières du Burkina Faso: cas de la reserve de la biosphere de la mare aux hippopotames. In: Ba AT, Madsen JE, Sambou B (Eds) Atelier sur flore, vegetation et Biodiversité au Sahel. Aarhus University Press, Aarhus Denmark, AAU Reports 39: 75–86.

Bénin PNF (2004) Plan national forestier du Bénin, Cotonou, Bénin. http://www.un.org/esa/forests/pdf/national_reports/unff4/benin.pdf

Biaou SSH (2009) Tree recruitment in West African dry woodlands: The interactive effects of climate, soil, fire and grazing. PhD thesis. Wageningen University, Wageningen.

Brand R (2001) Diversité ethnique et appropriation des cultes Vodoun dans une population de réfugiés au Sud Bénin. Outre-mers économiques: de l'Histoire à l'actualité du XXIe siècle, 269–297. https://doi.org/10.3406/outre.2001.3852

CARDER (2002) Plan de campagne agricole 2001–2002. Ouémé – Plateau Secteur Kétou. Secteur agricole, Kétou Benin, 69 pp.

Chevalier A (1910) Le Pays des Hollis et les régions voisines. 1 fascicule, Paris.

Chiu CH, Wang YT, Walther BA, Chao A (2014) Improved nonparametric lower bound of species richness via a modified Good-Turing frequency formula. Biometrics 70(3): 671–682. https://doi.org/10.1111/biom.12200

Colwell RK, Coddington JA (1994) Estimating terrestrial biodiversity through extrapolation. Philosophical Transactions of the Royal Society of London – Series B, Biological Sciences 345(1311): 101–118. https://doi.org/10.1098/rstb.1994.0091

Cords MC (1987) Demography of Blue Monkeys in the Kakamega Forest, Kenya. International Journal of Primatology 8: 1–546.

Cousin S (2018) Etat de l'art de Gou. Pérégrinations d'un dieu du progrès, hier et aujourd'hui. In: Murphy M, Houénoudé D (Eds) Création contemporaine et patrimoine royal au Bénin: autour de la figure du Dieu Gou. HICSA et Presse de l'Université d'Abomey Calavi, 22–43.

Couvreur TLP, Dauby G, Blach-Overgaard A, Deblauwe V, Dessein S, Droissart V, Hardy OJ, Harris DJ, Janssens SB, Ley AC, Mackinder BA, Sonké B, Sosef MSM, Stévart T, Svenning J-C, Wieringa JJ, Faye A, Missoup AD, Tolley KA, Nicolas V, Ntie S, Fluteau F, Robin C, Guillocheau F, Barboni D, Sepulchre P (2021) Tectonics, Climate and the Diversification of the Tropical African Terrestrial Flora and Fauna. Biological Reviews of the Cambridge Philosophical Society 96(1): 16–51. https://doi.org/10.1111/brv.12644

Demenou BB, Piñeiro R, Hardy OJ (2016) Origin and History of the Dahomey Gap Separating West and Central African Rain Forests: Insights from the Phylogeography of the Legume Tree Distemonanthus Benthamianus. Journal of Biogeography 43(5): 1020–1031. https://doi.org/10.1111/jbi.12688

Demenou BB, Doucet J-L, Hardy OJ (2018) History of the Fragmentation of the African Rain Forest in the Dahomey Gap: Insight from the Demographic History of Terminalia Superba. Heredity 120(6): 547–561. https://doi.org/10.1038/s41437-017-0035-0

Devineau JL (1975) Etude quantitative des forêts galeries de Lamto (Moyenne Côte d'Ivoire). PhD Thesis, Université Pierre et Marie Curie, Paris VI.

Droissart V, Dauby G, Hardy OJ, Deblauwe V, Harris DJ, Janssens S, Mackinder BA, Blach-Overgaard A, Sonké B, Sosef MSM, Stévart T, Svenning J-C, Wieringa JJ, Couvreur TLP (2018) Beyond Trees: Biogeographical Regionalization of Tropical Africa. Journal of Biogeography 45(5): 1153–1167. https://doi.org/10.1111/jbi.13190

Dupont LM, Weinelt M (1996) Vegetation history of the savanna corridor between the Guinean and Congolean rain forest during the last 150 000 years. Vegetation History and Archaeobotany 5(4): 273–292. https://doi.org/10.1007/BF00195296

Garnier A, Eichhorn B, Robion-Brunner C (2018) Impact de l'activité métallurgique au cours du dernier millénaire sur un système fluvial soudano-guinéen. Étude multi-proxy des archives sédimentaires de la vallée du Tatré (pays bassar, Togo). Géomorphologie: relief, processus, environnement 24(3): 257–276. https://doi.org/10.4000/geomorphologie.12446

Greiner A (1991) Nature Conservation and local people at Kakamega Forest. ASA Project. Stuttgart.

Guillaumet JL, Adjanohoun E (1971) La végétation de la Côte d'Ivoire. In: Avenard JM, Eldin E, Girard G, Sircoulon J, Touchebeuf P, Guillaumet JL, Adjanohoun E, Perraud A (Eds) Le milieu naturel de la Côte d'Ivoire. Mémoire ORSTOM, Paris 50: 156–263.

Hassler M (2020) World Plants: Synonymic Checklists of the Vascular Plants of the World. In: Roskov Y et al. (Eds) Species 2000 & ITIS Catalogue of Life, 2020-09-01 Beta, Leiden. www.catalogueoflife.org/col

Houngnon A (2014) Community Based Actions to Benefit a Threatened Plant Species: Case Study of *Bequaertiodendron oblanceolatum* in Ewe-Adapklame Remnant Forests in Benin. http://www.rufford.org/projects/alfred_houngnon [accessed 15.09.2014]

Houngnon A (2015) Propagation of native trees by local communities to provide food for primates in the forests of Ketou: a new challenge for habitat restoration in Benin Republic. http://www.rufford.org/projects/alfred_houngnon_0 [accessed 12.12.2015]

Houngnon A, Adomou AC (2021) Vascular plants of Ewe-Adakplame Relic Forest at Kétou in Benin, West Africa, Dryad, Dataset. https://doi.org/10.5061/dryad.z8w9ghxbg

Hutchinson J, Dalziel JM (1954–1972) Flora of West Tropical Africa (2nd ed. Vol. I–III). Crown Agents for Oversea Governments and Administrations, London.

INSAE (2016) Effectif de la population des villages et quartiers de ville du Bénin. RGPH-4 de 2013, Cotonou Bénin, 20 pp.

IUCN (2002) Evaluation of Nominations of Natural and Mixed Properties to the World Heritage List, Gland.

Jenik J (1994) The Dahomey Gap: An important issue in African phytogeography. Mémoire Société Biogéographie 4(3): 125–133.

Juhé-Beaulaton D (2010) Forêt sacrées et sanctuaires boisés. Edition Karthala, Paris, 280 pp.

Lebrun J-P (2001) Introduction à la flore d'Afrique. Paris: Cirad, Ibis Press, 213 pp.

LPWG (2017) Phylogeny and classification of the Leguminosae (Legume Phylogeny Working Group): A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny. Taxon 66(1): 47–77. https://doi.org/10.12705/661.3

Martin P (2008) Influence de la fragmentation forestière sur la régénération des espèces arborées dans le Sud-Ouest de la Côte d'Ivoire. University of Geneva, Geneva.

Natta AK (2003) Ecological assessment of riparian forests in Benin. Phytodiversity, phytosociology and spatial distribution of tree species. PhD Thesis, Wageningen University, The Netherlands.

Neuenschwander P, Sinsin B, Goergen G (2011) Protection de la Nature en Afrique de l'Ouest: Une Liste Rouge pour le Bénin. Nature Conservation in West Africa: red list for Benin. International Institute of Tropical Agriculture, Ibadan, 365 pp.

Oksanen J, Guillaume Blanchet F, Friendly M, Kindt R, Legendre P, McGlinn D, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Szoecs E, Wagner H (2017) Vegan: Community Ecology Package. Version 2.4-2. https://CRAN.R-project.org/package=vegan [accessed 30.06.2017]

Oloukoï J, Mama VJ, Agbo FB (2007) Modélisation de la dynamique de l'occupation des terres dans le département des collines au Bénin. Télédétection 6(4): 305–323.

Palmer MW (1990) The estimation of species richness by extrapolation. Ecology 71(3): 1195–1198. https://doi.org/10.2307/1937387

Paradis G (1977) Observation sur l'Holocène récent du Sud-Bénin (ex-Dahomey). Bulletin de liaison de l'Association Sénégalaise de l'Etude du Quaternaire 51: 49–73.

Poorter L, Bongers F, Kouamé FN, Hawthorne WD (2004) Biodiversity of West African Forests: An ecological atlas of woody plants species. CABI Publishing, Cambridge, 521 pp. https://doi.org/10.1079/9780851997346.0000

R-Core-Team (2016) R: a language and environment for statistical computing. R. Foundation for Statistical Computing, Vienna. version 3.3.2. http://www.R-project.org [accessed 31.10.2016]

Raunkiaer C (1934) The Life Forms of Plants and Statistical Plant Geography. Clarendon Press, London, 632 pp.

Richards PW (1939) Ecological studies on the rain forest of southern Nigeria. N°1 the structure and floristic composition of the primary forest. Journal of Ecology 27(1): 1–61. https://doi.org/10.2307/2256298

Richards PW (1973) Africa, the "Odd man out." In: Meggers BJ, Ayensu ES, Duckworth WD (Eds) Tropical Forest Ecosystems in Africa and South America: A Comparative Review. Washington: Smithsonian Institution Press, 212–239.

Salzmann U, Hoelzmann P (2005) The Dahomey Gap: An abrupt climatically induced rain forest fragmentation in West Africa during the late Holocene. The Holocene 15(2): 1–10. https://doi.org/10.1191/0959683605hl799rp

Sosef MSM, Dauby G, Blach-Overgaard A, van der Burgt X, Catarino L, Damen T, Deblauwe V, Dessein S, Dransfield J, Droissart V, Duarte MC, Engledow H, Fadeur G, Figueira R, Gereau RE, Hardy OJ, Harris DJ, de Heij J, Janssens S, Klomberg Y, Ley AC, Mackinder BA, Meerts P, van de Poel JL, Sonké B, Stévart T, Stoffelen P, Svenning J-C, Sepulchre P, Zaiss R, Wieringa JJ, Couvreur TLP (2017) Exploring the Floristic Diversity of Tropical Africa. BMC Biology 15(1): e15. https://doi.org/10.1186/s12915-017-0356-8

Swaine MD (1996) Rainfall and soil fertility as factors limiting forest species distribution in Ghana. Journal of Ecology 84(3): 419–428. https://doi.org/10.2307/2261203

Tossou MG (2002) Recherche palynologique sur la végétation Holocène du Sud-Bénin (Afrique de l'Ouest). PhD Thesis, Université de Lomé, 136 pp.

Vooren F, Sayer J (1992) Côte d'Ivoire. In: Sayer JA, Harcourt CS, Collins NM (Eds) The Conservation Atlas of Tropical Forests: Africa. IUCN and Macmillan Publishers, UK, 133–142. https://doi.org/10.1007/978-1-349-12961-4_16

Wantchecon AM (1983) Contribution à l'histoire des technologies anciennes du Bas-Bénin. L'exemple du, travail du fer à Allada des origines du royaume à la conquête aboméenne en J.E.R., Maîtrise en Histoire, U.N.B., E.N.S., 48 pp.

White F (1983) The vegetation of Africa. A descriptive memoir to accompany the Unesco/AETFA/UNSO. Natural Resources Research 20: 1–356.